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A bibliometric performance analysis of publication productivity in the laser powder bed fusion additive manufacturing in Nigeria

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Abstract: The paper aims to investigate research productivity in laser powder bed fusion (LPBF) through additive manufacturing technology by performing a bibliometric analysis. The search strategy was conducted using the Scopus database and its analysis tool to first identify productive LPBF authors and then examine their productivity over the last 10 years (2015–2025). The study examines the quantitative and qualitative publication performance of countries and authors. Additionally, the documents were analyzed in VOS viewer, a software tool used to create and visualize bibliometric networks, which allows for collaboration patterns and co-authorship networks to be identifiable, co-occurrence of keywords, and have a total citation analysis. This reflects their solidified place in the global scientific community. The over world paper results showed that China and the United States are the most active countries in this field, based on contributions from various authors and institutions. The second section, which focused on publications from Nigeria, indicated that the University of Nigeria has produced the highest number of documents in this domain.

1. Introduction

Additive manufacturing, also known as layer-by-layer deposition, is a technology that has become widely utilized in various fields such as automotive, aerospace, also in the medical field, because it gives more complex parts that are mostly impossible to realize by traditional methods, with lower costs and less residue (Igwe *et al.*, 2025) (Haile *et al.*, 2025; Igwe & Oniko, 2022). It is a technology that helps to fabricate objects layer by layer using different sources of energy depending

on the material used (metal, polymer, ceramic…) (Igwe *et al.*, 2025). Different processes are used in additive manufacturing, among the most commonly used methods, especially for metal fabrication; there is Directed Energy Deposition (DED) and Powder Bed Fusion (PBF) (Igwe *et al.*, 2024; Igwe *et al.*, 2025; Igwe *et al.*, 2025; Igwe *et al.*, 2025)techniques. The first technique, which is also known by laser coating relies on the introduction of the material in the form of a metal powder into a heat source such as a laser, which melts the metal particles together as they are deposited, while the second technique is based on the fusion of the metal powder in an inert gas chamber by a high-power laser, that aims to melt the metal particles layer by layer (Akhrif *et al.*, 2023) PBF is subdivided into several techniques, including Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), Selective Laser Sintering (SLS), and Selective Laser Melting (SLM) (Singh *et al.*, 2019). On the other hand, DED encompasses methods such as Electron Beam Freeform Fabrication (EBFFF), Laser Engineering Net Shaping (LENS), Laser Consolidation, Direct Light Fabrication (DLF), and Wire Arc Additive Manufacturing (WAAM). Prior to now, metallic parts were fabricated traditionally or through subtractive methods (Igwe *et al.*, 2025; Igwe & Ozoegwu, 2024) (Ononiwu *et al.*, 202), however, this days additive manufacturing can be used to fabricate almost anything (Akhrif *et al.*, 2025; Benjamin *et al.*, 2023; Igwe & Oniko, 2022; Igwe & Ononiwu, 2025; Mwema *et al.*, 2025; Rihani *et al.*, 2025)
Additive manufacturing has recently gained increasing interest in the production of Metal matrix composites (Akhrif *et al.*, 2023; Bensada *et al.*, 2023; Ouazzani *et al.*, 2022; Oulkhir *et al.*, 2025; Zahra *et al.*, 2024). Although the full application of metals alloys and its corresponding composites has not been fully achieved when compared to other metal materials fabricated through other conventional means, the potential of the synergy between the class of metal material and its usefulness can be realized through additive manufacturing. Some of these applications includes in the biomedical engineering application, Automobile, Aerospace and space. The advantages particularly of using metal matrix composites (MMC's) in biomedical application (Yu *et al.*, 2019), is the possibility of adjusting the mechanical and corrosion properties. With SLM, they have the potential to eliminate the problem of bone remodeling due to mismatch in mechanical properties by varying the compositions of these MMNCs continuously or discretely to match the required properties (Sing et al., 2016). A thorough review on MMNCs in biomedical applications, in particular for implants, devices with enhanced wear resistance and hard tissue engineering such as bone and tooth, have been given by Bose et al. *(Bose et al.*, 2018). Chen et al.(Chen *et al.*, 2017) studied the corrosion behavior of SLM Ti-TiB MMNCs in simulated body fluid and concluded that they have better corrosion resistance than pure titanium produced by SLM as the TiB particles act as micro-cathode and the titanium matrix acts as anode during corrosion process, which facilitates the formation of a protective film on the surface, in the Hank's solution at body temperature (Chen *et al.*, 2017). For automobile and aerospace applications. This is especially relevant as global energy demand continues to rise, with an expected increase of 76.9% between 2021 and 2050 (Careri *et al.*, 2023). It enables the design of complex and optimized geometries, which enhances the thermal efficiency of systems (López-Barroso *et al.*, 2024). Thanks to this technology, it is possible to create intricate internal structures, such as optimized flow channels, thereby maximizing the surface area for contact between hot and cold fluids. This leads to improved thermal performance and more efficient energy management (Byiringiro *et al.*, 2024). Additionally, 3D printing allows for the production of lighter exchangers while reducing costs and manufacturing time (Anwajler, 2024). This method also offers advanced customization, allowing for precise adaptation to the specific needs of applications, and facilitates the use of advanced materials with better thermal and mechanical properties (Zhou *et al.*, 2024).

An analysis of the available literatures on selective laser melting of MMNCs has revealed its importance and explored the possibilities it offers for engineering applications. The SLM technique will be increasingly employed for fabricating high quality, low cost and repeatable complex geometrical MMNCs parts in automotive, aerospace, electronics and biomedical industries (Nandiyanto *et al.*, 2024). It aids manufacturing in these areas to deliver new customized products quicker into application and has the potential to gain more consumer markets.

Additive manufacturing (AM) offers a solution to this limitation by enabling the fabrication of intricate shapes and internal structures that were previously unachievable. These advanced receiver designs not only improve thermal efficiency but can also contribute to lowering the capital cost of CSP plants by optimizing material usage and performance. **Figure 1** show examples of such complex geometries, which are challenging to manufacture traditionally but can be realized through additive manufacturing. Bibliometrics is a statistical method used to quantitatively analyze research articles on a specific topic using mathematical techniques (Wang & Su, 2020 ; Julius *et al.*, 2021). It also allows for the evaluation of study quality, identification of key research areas, and prediction of future research directions (Passas 2024; Laita *et al.*, 2024). In addition, bibliometric indicators such as publication counts, citation analysis, h-index, and journal impact factor offer objective insights into the productivity and influence of authors, institutions, and countries (Lrhoul *et al.*, 2023). This helps scholars and decision makers assess scientific performance and allocate research funding more strategically. The online database Scopus collects the majority of relevant research articles and provides integrated analysis tools to generate representative data (Arachchige *et al.*, 2021). It includes features such as citation tracking, co-authorship networks, subject classifications, and affiliation analysis, enabling users to explore collaboration trends and disciplinary impacts. Additionally, search results from Scopus can be exported to software such as VOS viewer for more in-depth analysis (Aichouch *et al.*, 2025; Hammouti *et al.*, 2025; Kadda *et al.*, 2025). VOS viewer, along with other tools like CiteSpace and Bibliometrix (based on R) (Derviş et al., 2020), enables advanced visualizations and mapping of bibliographic data, including co-citation networks, keyword co-occurrence, and temporal trends. These tools support the discovery of research frontiers and the identification of thematic clusters, facilitating a better understanding of how scientific knowledge evolves over time.

This study aims to conduct a bibliometric analysis from 2015 to 2025 on productivity in the field of LPBF additively manufactured materials over the world followed by a focus on Nigerian Universities. It focuses on identifying the most influential authors in this field, meaning those with the highest number of published articles, the most cited affiliations, the greatest published countries, as well as the targeted areas of study. This expansive search strategy aims to identify relevant literature on leadership development in higher education and university contexts, providing a strong databased foundation for further bibliometric analysis.

1. Methodology

The literature on LPBF additive manufacturing published between the last ten years was retrieved from the Scopus database. The search terms used to identify relevant publications included ‘laser powder bed fusion additive manufacturing’, ‘LPBF additive manufacturing’ and ‘PBF additive manufacturing’, with these phrases being applied as keywords in the title. The data extracted from the documents that met the criteria included publication year, authors, co-authors, and affiliations, all of which were exported in CSV format. VOS viewer was employed to analyze co-authorship. VOS ("visualization of similarities") was a concept developed less than two decades ago for analyzing and visualizing patterns within data (Eck & Waltman, 2007).

2. Results and Discussion

3.1. Over the world

3.1.1. Scopus analysis

Figure 1 highlights the most prolific authors worldwide in the field of Laser Powder Bed Fusion (LPBF) between 2015 and 2025.

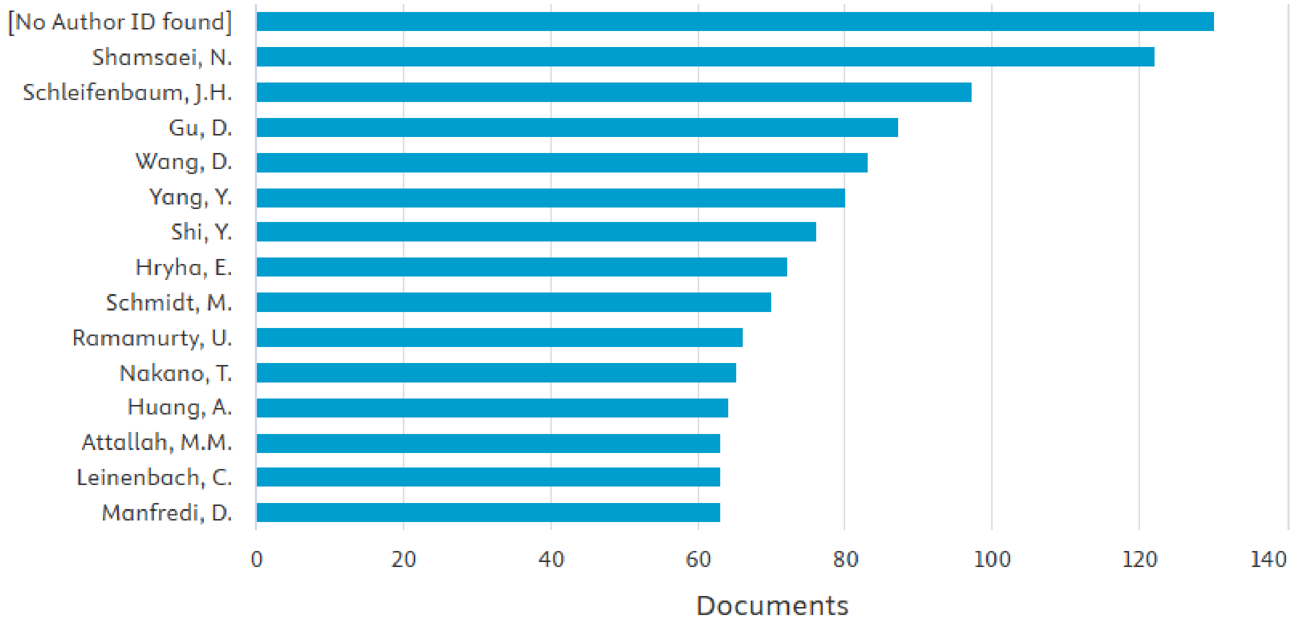

Fig.1. Produced documents by various authors in LPBF additive manufacturing over the world from 2015 to 2025.

The No Author ID found ranks first with approximately 135 publications, reflecting a considerable body of work. Among the identified researchers, Nima Shamsaei leads with around 120 publications, widely recognized for his contributions on fatigue and durability of LPBF-fabricated alloys, particularly Ti-6Al-4V used in aerospace and biomedical applications. Johannes Henrich Schleifenbaum, with about 100 publications, has focused on process optimization, industrial integration, and simulation-driven manufacturing strategies. Dongdong Gu (≈85) and Dong Wang (≈80) have significantly contributed to understanding process–microstructure–property relationships, emphasizing the role of laser parameters on microstructural evolution and mechanical performance. Yang Yang (≈75) and Yi Shi (≈70) have advanced the field through numerical modeling and thermodynamic analyses of solidification and residual stress formation. Evgeny Hryha, with roughly 65 publications, has specialized in powder metallurgy and material purity, while Michael Schmidt (≈65) has explored laser technology innovations and their industrial applications. Umapathy Ramamurty (≈60) has provided critical insights into mechanical properties and fracture mechanisms of LPBF alloys, whereas Takayoshi Nakano (≈58) has worked on tailoring microstructures to enhance functional performance. Aijun Huang (≈57) has investigated the reliability and performance of LPBF components, Moataz M. Attallah (≈55) has focused on advanced alloy systems for aerospace applications, and Claudio Leinenbach (≈55) has developed innovative alloy compositions, particularly nickel-based superalloys and titanium alloys. Finally, Daniele Manfredi (≈55) has been active in powder characterization, process parameter optimization, and mechanical property evaluation of LPBF-fabricated materials. Collectively, these authors represent the leading contributors driving global research in LPBF, with their work converging on process optimization, alloy design, material performance, and industrial applications in high-value sectors such as aerospace, biomedical engineering, and energy. The graph represented in **Figure 2** highlights the institutions with the highest number of publications in LPBF between 2015 and 2025 over the world, complementing the author-level analysis previously discussed.

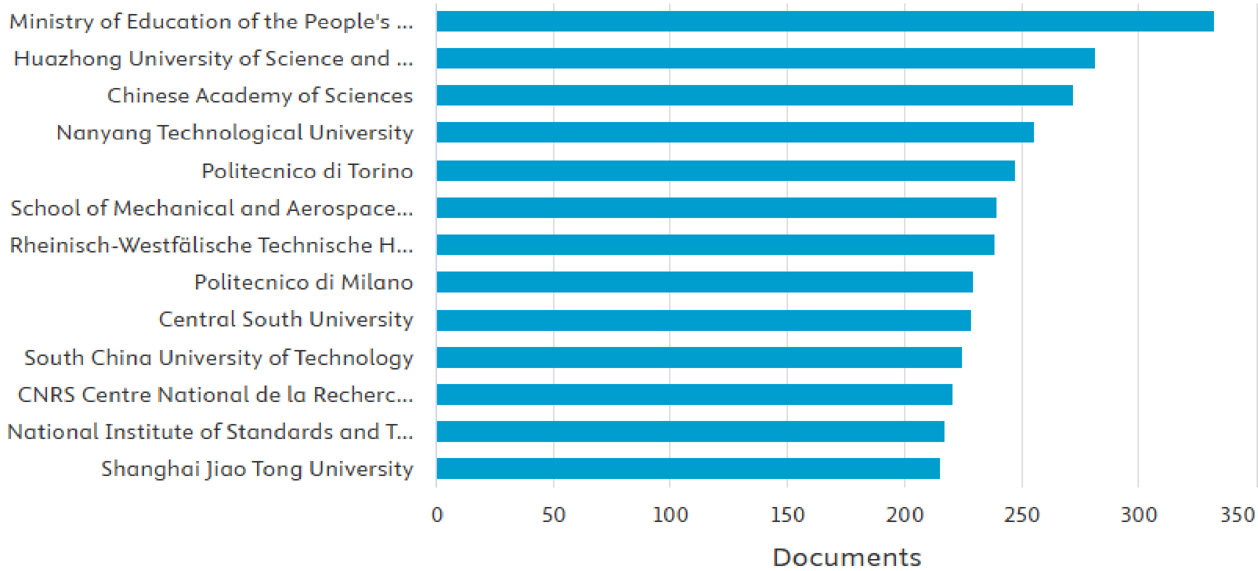

Fig.2. Produced documents by various institutions over the world in LPBF additive manufacturing from 2015 to 2025.

The Ministry of Education of the People's Republic of China leads with more than 330 publications, reflecting the central role of Chinese universities and laboratories in driving global LPBF research. Close behind, Huazhong University of Science and Technology and the Chinese Academy of Sciences contribute over 280 and 270 publications, respectively, aligning with the prolific output of leading Chinese researchers such as Dongdong Gu, Dong Wang, Yang Yang, and Yi Shi, who are directly affiliated with these institutions. Outside China, Nanyang Technological University (Singapore) emerges as a major hub (≈260 publications), reinforcing the prominence of Southeast Asia in LPBF research. In Europe, Politecnico di Torino and Politecnico di Milano (≈240–220 publications each) demonstrate Italy's strong research presence, which is consistent with the contributions of Daniele Manfredi in powder characterization and process optimization. Similarly, Rheinisch-Westfälische Technische Hochschule and School of Mechanical and Aerospace Engineering rank among the top contributors, connecting to figures like Johannes Henrich Schleifenbaum and Michael Schmidt, who are well-known for their work on process innovation and industrialization of LPBF. Meanwhile, Central South University and South China University of Technology (≈220 publications each) underline the breadth of Chinese academic engagement in this domain. On the international stage, research organizations such as Centre National de la Recherche Scientifique (CNRS, France) and the National Institute of Standards and Technology (NIST, USA) play a critical role, often focusing on alloy design, standardization, and mechanical testing, in alignment with the global contributions of Moataz M. Attallah, Claudio Leinenbach, and Nima Shamsaei. Finally, Shanghai Jiao Tong University adds significant contributions (≈215 publications), further consolidating China's dominance. Collectively, this institutional landscape mirrors the individual author network observed earlier, with Chinese, European, and North American research groups providing the backbone of LPBF knowledge, as illustrated in **Figure 3**.

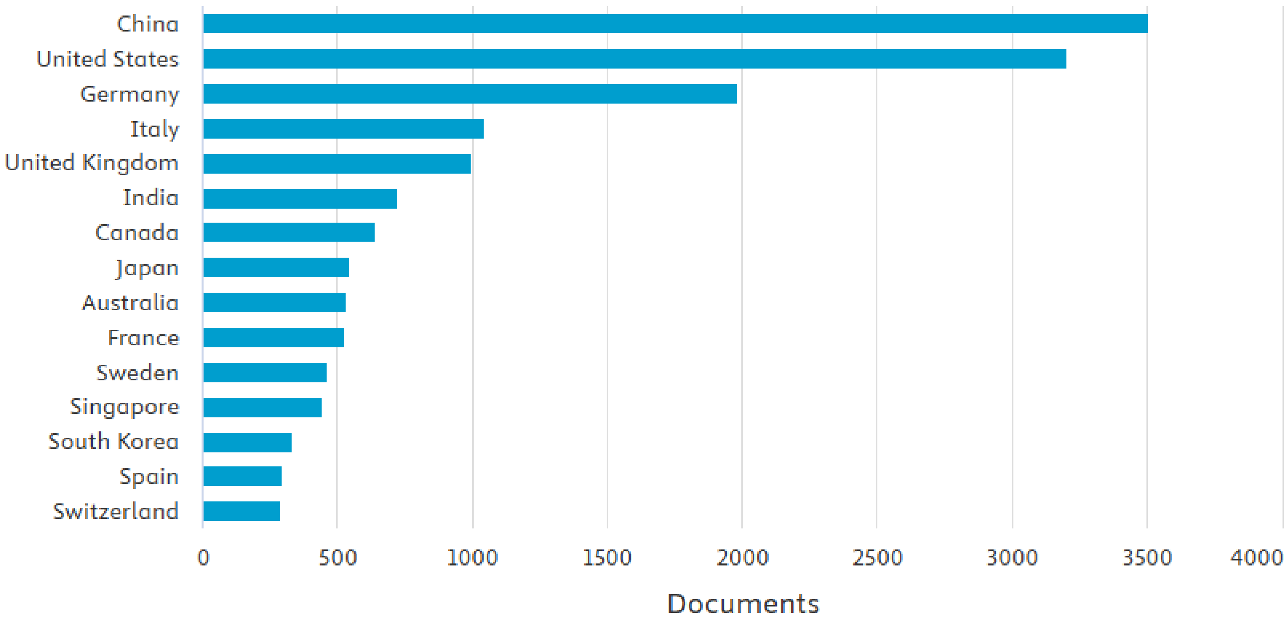

Fig.3. Produced documents by over the world countries in LPBF additive manufacturing from 2015 to 2025.

From this **Figure**, China clearly dominates LPBF research with nearly 3,500 publications, followed closely by the United States with over 3,200 and Germany with around 2,000, confirming their central role in advancing the field. Italy and the United Kingdom also make strong contributions, while countries such as India, Canada, Japan, and Australia are emerging hubs with over 500 publications each, reflecting the globalization of LPBF research. Other European nations, including France, Sweden, and Switzerland, further consolidate Europe's strong presence, and Singapore stands out as a regional leader in Southeast Asia. These documents, published by different countries and authors, were produced in various years, as shown in **Figure 4**.

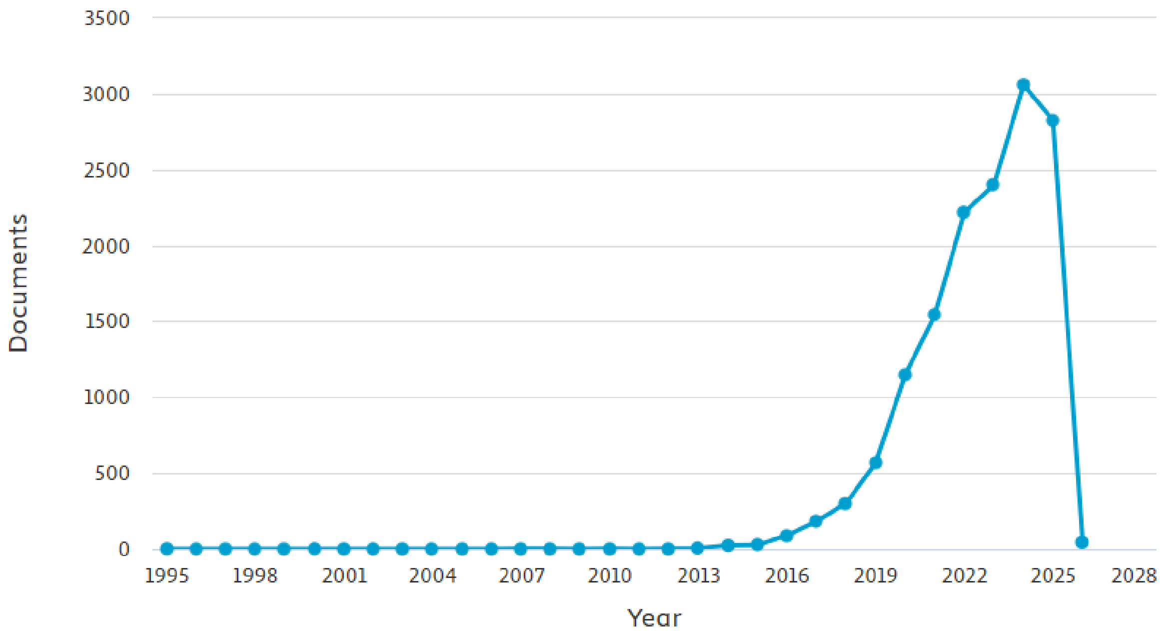

Fig.4. Documents produced in LPBF additive manufacturing by year over the world from 2015 to 2025

The graph illustrates an exponential increase in the number of published documents, starting with fewer than 100 per year until 2016, and then rising sharply to peak at over 3,000 publications in 2024, before dropping abruptly in 2025, likely due to incomplete data for the current year.

The pie chart indicated in **Figure 5**, shows that LPBF research between 2015 and 2025 is heavily concentrated in two main fields: Engineering (35.5 %) and Materials Science (33.0 %), reflecting the applied and technological focus on process optimization, alloy development, and enhancement of mechanical properties. Physics and Astronomy (13.7 %) represents the third most significant domain, highlighting the importance of fundamental studies on microstructure, solidification, and residual stresses to support industrial applications. Other disciplines are much less represented: Computer Science (4.9 %), Mathematics (2.9 %), Chemical Engineering (2.5 %) and others (7.5%), illustrating the targeted specialization of LPBF research on high-value areas. This complete distribution of publications confirms that most scientific efforts converge on process engineering and materials science, while more theoretical or peripheral disciplines contribute marginally, consistent with the concentration observed at the level of leading authors, institutions, and countries in the field.

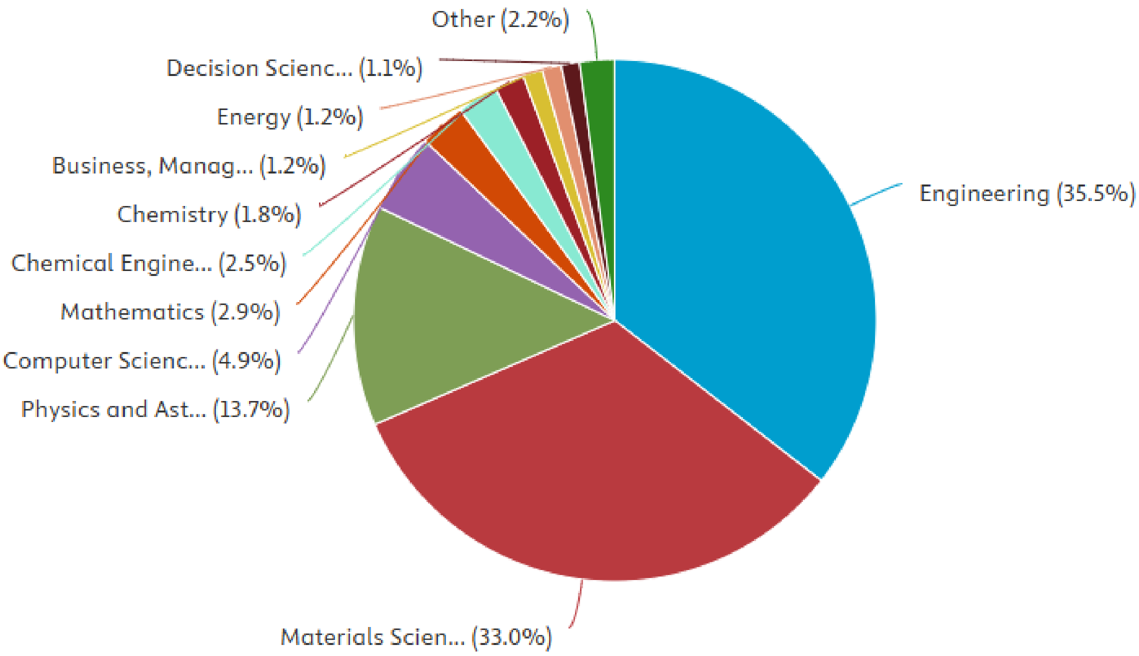

Fig.5. Different fields of produced documents in LPBF additive manufacturing over the world from 2015 to 2025.

3.2. Nigeria-focused

3.2.1. Scopus analysis

Figure 6 shows the number of publications by various authors on productivity LPBF additive manufacturing within Nigerian universities from 2015 to 2025. The x-axis represents the number of documents (publications), while the y-axis lists the authors' names. Based on the bar chart (**Figure 6**) and supplementary research, Igwe Nnamdi Chukwunenye emerges as the most influential author, distinguished by multiple publications primarily focused on LPBF of aluminum alloys, particularly $AlSi_{10}Mg$, with emphasis on optimizing process parameters to enhance corrosion resistance, surface quality, and mechanical performance, as well as exploring aluminum-based metal matrix composites reinforced with materials like rice husk ash (RHA). In contrast, authors such as Akinlabi Esther T contributed in a single publication addressing topics like LPBF parameter optimization for Co-Cr dental alloys and numerical modeling of residual stresses in Ti-6Al-4V alloys, while Ajao, K. S. focused on processing novel biocompatible titanium alloys, and Abdulhamid Abubakar Abba Abdulhamid examined challenges associated with LPBF in aluminum alloys. The singular contributions from these researchers and the other authors (**Figure 1**) as well as other not indicated authors names, because Scopus results allow just limited names in the bar chart) suggest specialized or emerging interests, whereas, Igwe Nnamdi Chukwunenye multiple studies indicate a sustained and established research focus, positioning him as a leading authority in this niche yet developing field within Nigerian academia.

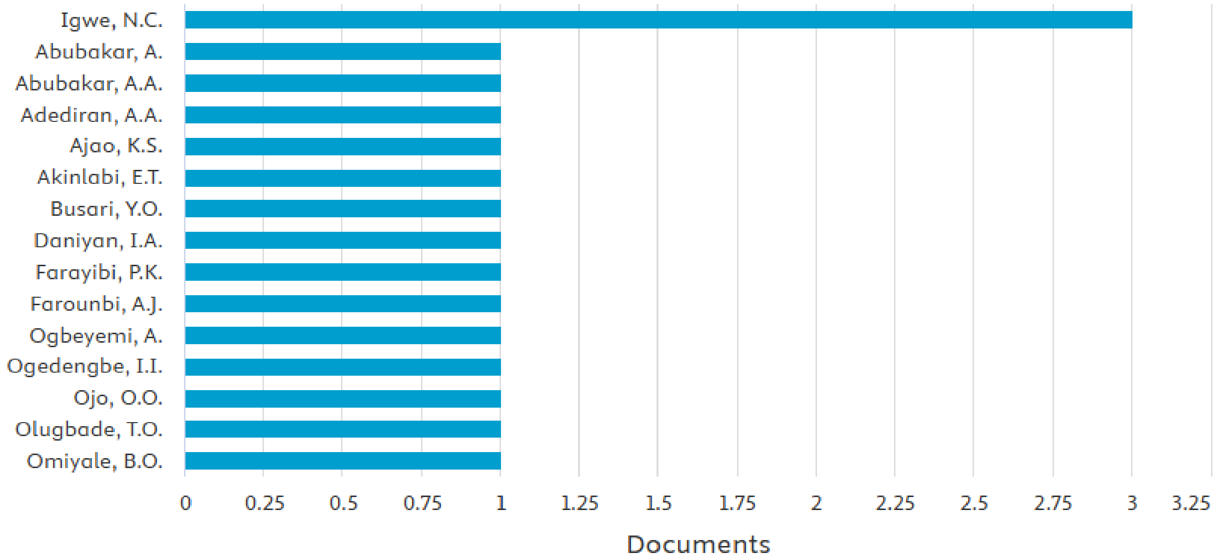

Fig.6. Produced documents by various authors in LPBF additive manufacturing within Nigerian universities from 2015 to 2025.

The bar chart presents in **Figure 7**, illustrate the research productivity of various institutions associated with the previously mentioned authors in laser powder bed fusion additive manufacturing within Nigerian universities from 2015 to 2025. Productivity is measured by the number of publications, with the x-axis representing the number of documents and the y-axis listing the names of the institutions.

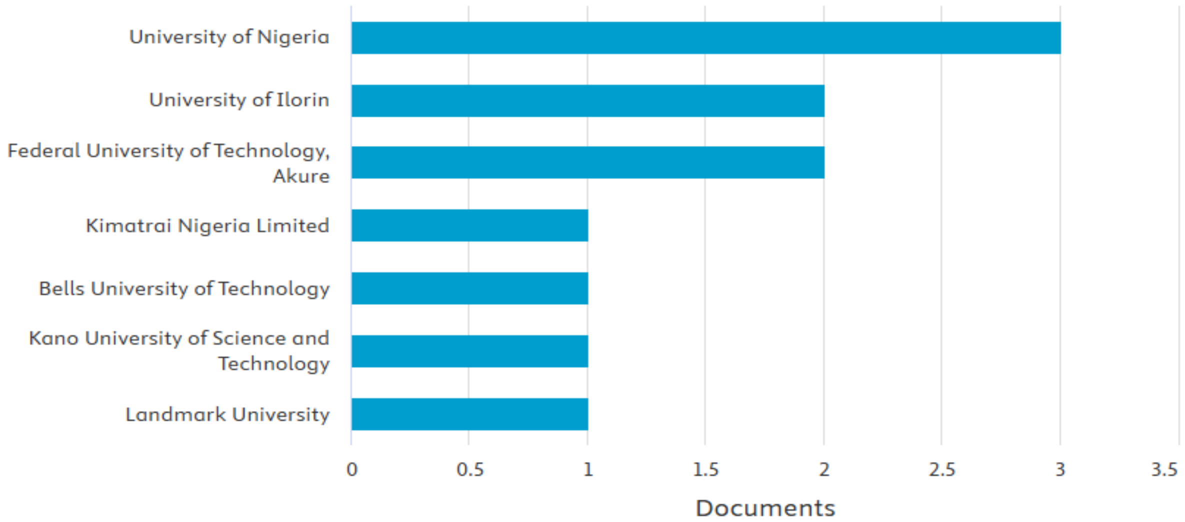

Fig.7. Produced documents by various Nigerian universities in LPBF additive manufacturing from 2015 to 2025.

According to the bar charts, the University of Nigeria emerges as the leading institution in publication productivity on LPBF additive manufacturing, with three published documents, primarily driven by the work of Igwe Nnamdi Chukwunenye, the most prolific author affiliated with the university. In comparison, the University of Ilorin and the Federal University of Technology, Akure, each contributed two publications, while Bells University of Technology, Kano University of Science and Technology, Landmark University and Kimatrai Nigeria limited produced only one publication each. This distribution highlights a concentration of research expertise within a few institutions, positioning the University of Nigeria as a central hub for advancing this specialized and emerging technology within the country's academic landscape. The number of documents produced by the previously mentioned authors, representing various affiliations, increased gradually over the years, as shown in **Figure 8**.

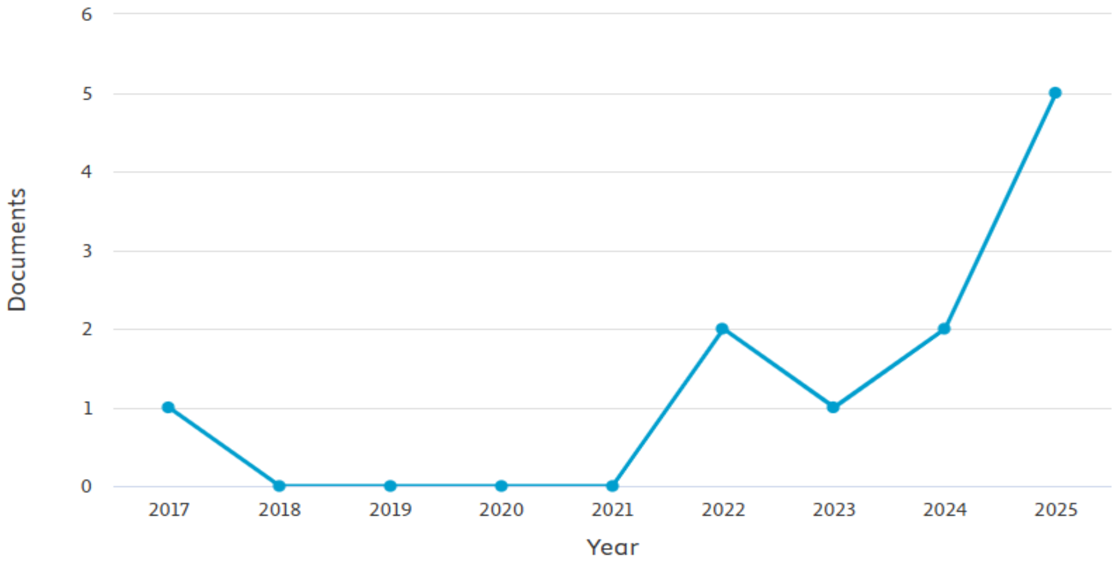

Fig.8. Documents produced in LPBF additive manufacturing by year within Nigerian universities from 2015 to 2025.

The data presented in the **Figure** shows an initial slow start, followed by a period of stagnation, and then a notable increase in research activity. After a single publication in 2017, there was little to no output between 2018 and 2021, indicating limited engagement with the field during that period. Research interest began to rise in 2022 with two publications, experienced a slight decline in 2023 with one publication, and then increased steadily in 2024 with two publications, culminating in a peak of five publications in 2025. This upward trend in recent years reflects growing awareness, more substantial institutional commitment, and expanding research capacity in LPBF, establishing it as an emerging and increasingly significant area of study within Nigerian academia.

From 2015 to 2025, publications on LPBF additive manufacturing in Nigerian universities have addressed various research areas, as illustrated in **Figure 9**. The pie chart shows that publications in LPBF additive manufacturing are distributed across several fields, with the highest focus on Engineering (37.5%), followed by Computer Science (20.8%) and Materials Science (20.8%). Engineering research emphasizes practical applications and process optimization, such as determining optimal parameters for material properties, exemplified by Akinlabi Esther T's work on numerical modeling of residual stresses in Ti-6Al-4V. The equal shares of Computer Science and Materials Science reflect an interdisciplinary approach, where material-specific studies, like Nnamdi Igwe Nnamdi Chukwunenye's research on aluminum alloys and composites, are supported by computational methods, including Sohail Akhtar Syed Sohail's use of machine learning to predict melt pool geometry and microstructure. The remaining publications in Physics and Astronomy (12.5%) and Mathematics (8.3%) provide the theoretical foundations and analytical frameworks necessary to understand laser–material interactions and support modeling in the other fields.

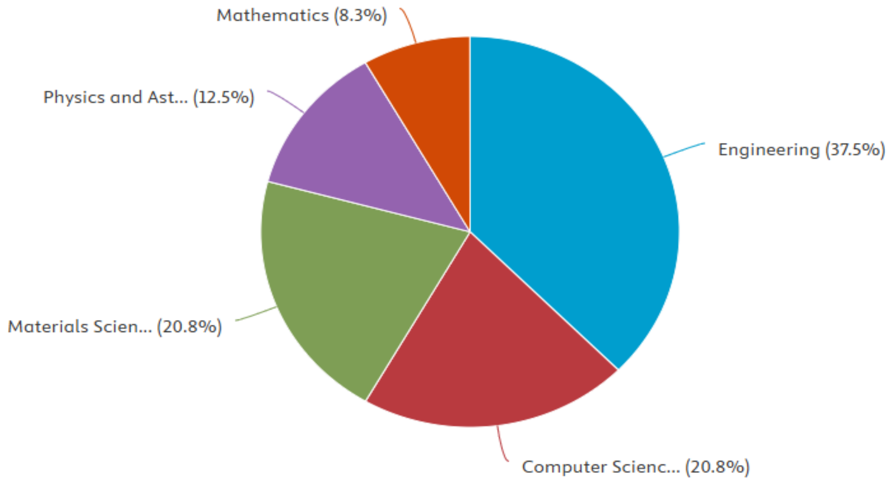

Fig.9. Different fields of produced documents in LPBF additive manufacturing within Nigerian universities from 2015 to 2025.

3.2.2. VOSviewer analysis

The VOSviewer network visualization shown in **Figure 10** depicts co-authorship patterns among researchers on LPBF additive manufacturing in Nigerian universities from 2015 to 2025, with nodes representing authors sized by publication output or contribution, and edges showing collaborative links, while colors indicate clusters of frequent collaborators (Ech-chihbi *et al.*, 2022 ; Kachbou *et al.*, 2025).

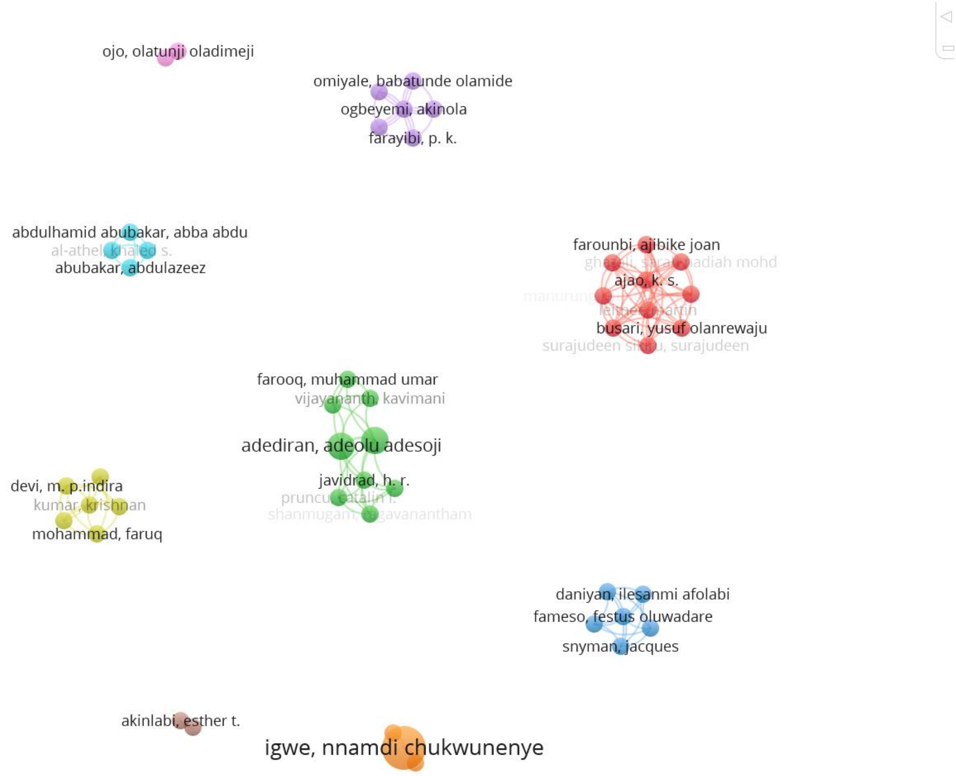

Fig.10. Co-authors network visualisation of produced documents in LPBF additive manufacturing within Nigerian universities from 2015 to 2025.

The blue cluster, including Festus Oluwadare fameso and Ilesanmi Afolabi daniyan, reflects a moderately active collaboration network likely focused on engineering or materials studies. The red cluster, comprising P.K. Farayibi, Amos Babatunde Osasona, Ikeoluwa Ireoluwa Ogedengbe, and Akinola Ogbeyemi, is the most densely connected, indicating a highly productive research team contributing core publications. The green cluster, comprising Ajibike Joan Farounbi and K.S. Ajao, forms a smaller, tightly knit group, suggesting focused collaboration in computational modeling or materials characterization. The cyan/teal cluster is represented by Nnamdi Chukwunenye Igwe, whose substantial individual contributions stand out despite limited collaborations, highlighting him as a leading and influential researcher in the field with work that significantly advances LPBF studies in Nigeria. Yellow and orange clusters, including Abba Abdulhamid Abdulhamid Abubakar and Olatunji Oladimeji Ojo, indicate emerging or niche collaborations, while the purple cluster with Adeolu Adesoji Adediran and Monsuru Olalekan Ramoni reflects a small network with a specific thematic focus, possibly experimental or early-stage studies. Overall, the visualization highlights a mix of highly collaborative networks, emerging scholars, and influential individual contributors, illustrating the growing scholarly activity and increasing interdisciplinary collaboration in LPBF research in Nigeria.

An overlay visualization tool indicates the publication of articles over time by coloring different elements on the map according to their average year of publication, allowing for a chronological analysis of research trends. For example, earlier research might be shown in purple, while more recent research appears in yellow, illustrating the evolution of a topic's keywords and themes within the analyzed literature (Aichouch *et al.*, 2025 ; Kadda *et al.*, 2025). **Figure 11** indicates that Igwe contributes this year with yellow color, wile Abdulhamid Abubakar, akinlabi, and Javidrad published around 2020.

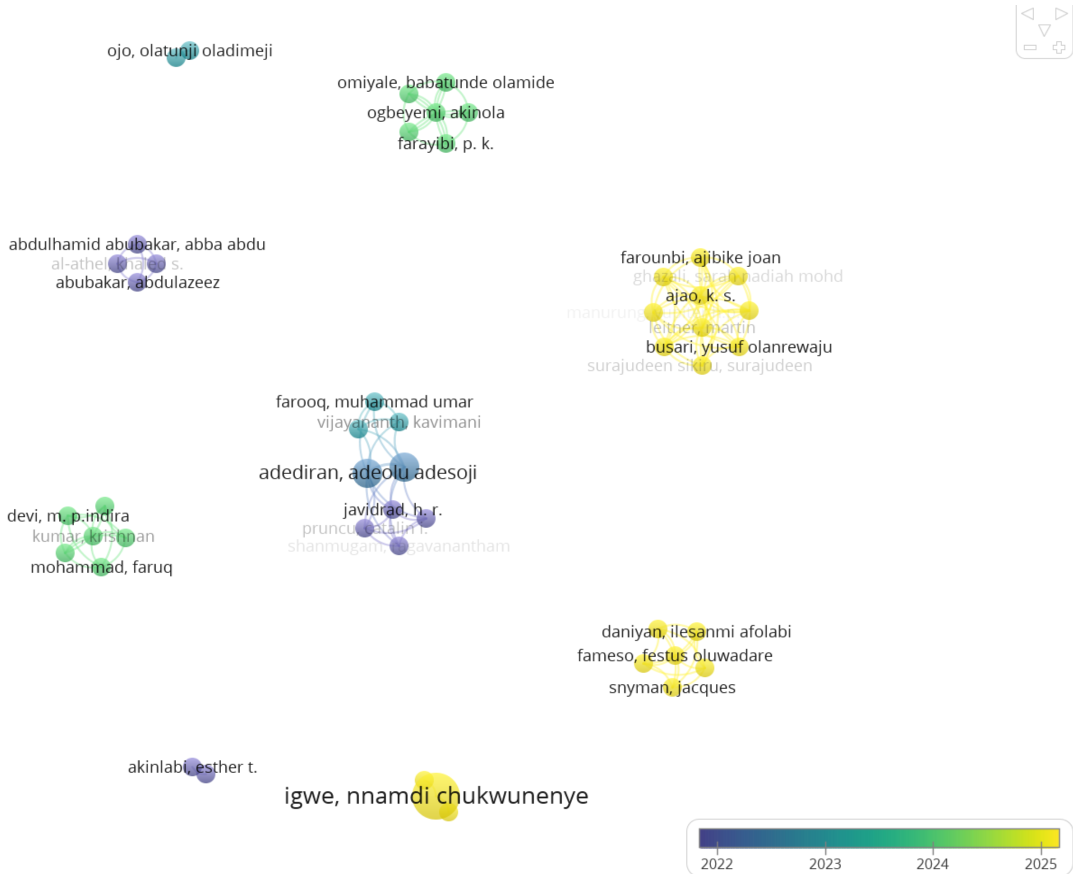

Fig. 11. Co-authors overlay visualisation of produced documents in LPBF additive manufacturing within Nigerian universities from 2015 to 2025.

The density visualization in **Figure 12** provides a heatmap-style depiction of the co-authorship network, focusing on publication productivity in LPBF research across Nigerian universities from 2015 to 2025. This map highlights areas of high author concentration and intense collaboration, serving as a valuable complement to the earlier cluster-based network analysis (Alshaikh, 2023; Amelia Kusniawati *et al.*, 2025). Importantly, the density visualization reinforces the presence and prominence of several core research groups within the field.

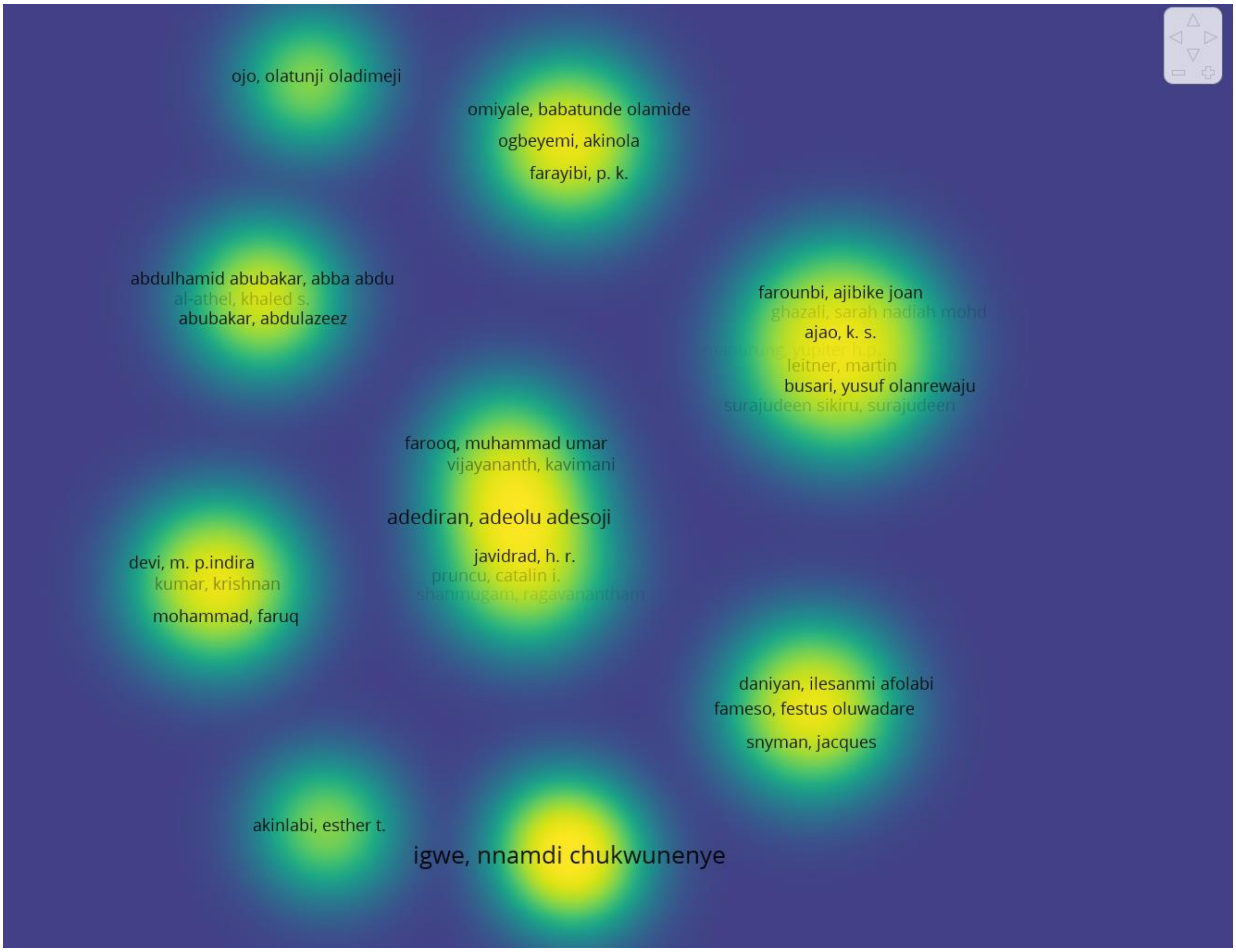

Fig. 12. Co-authors density visualisation of produced documents in LPBF additive manufacturing within Nigerian universities from 2015 to 2025.

The most prominent hotspot, shown in bright yellow and green, centers around Igwe, Nnamdi Chukwunenye, whose extensive network and substantial publication record indicate a leading role in the field. Another notable hotspot comprises Ramoni, Monsuru Olalekan, Adediran, and Adeolu Adesoji, reflecting strong and active collaboration. The visualization further highlights distinct contributions from Abdulhamid Abubakar and Abba Abdulhamid, alongside a large distinct bright region, including Osasona, Amos Babatunde, Ogbeyemi, Akinola, and Farayibi, P.K., signifying a highly collaborative and productive team. Additional key authors and their research networks are represented by Shuaib-Babata, Yusuf Lanre, Ajao, K.S., Busari, Yusuf Olanrewaju, and Farounbi, Ajibike Joan, while researchers such as Ojo, Olatunji Oladimeji, and Daniyan, Ilesanmi Afolabi contribute within smaller density. Overall, the presence of diverse authors across multiple hotspot illustrates that research in LPBF is both distributed and expanding, with numerous Nigerian scholars actively advancing knowledge through collaborative efforts.

Conclusion

This study examined the evolution of research on laser additive manufacturing, a field that is the evolution of metal fabrication through additive manufacturing, a field gaining momentum due to its potential in fabricating complex, high-performance metal, metal alloy and composite systems. Additive manufacturing enables the design of intricate geometries for heat exchangers, significantly improving energy efficiency and customization. Through a bibliometric analysis using Scopus and VOSviewer. Results reveal that China and the United States have the most publications in the world in LPBF during 2015–2025. In the focused study on Nigeria, Nnamdi Igwe of the University of Nigeria emerged as the most prolific author during this period. The mapping and quantitative indicators offer valuable insights for guiding future research efforts and fostering innovation in laser additive manufacturing.

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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

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